

# Effects of Listening Behaviors of a Social Robot on Adult's Motivation and Performance in Piano Practice

Ryuto Matsusaka, Masahiro Shiomi, and Tetsuya Takiguchi

**Abstract**—The landscape of education with social robots is evolving, especially within the realm of music education. However, past studies have focused on children as music learners and such verbal behaviors as praise. Therefore, it remains unknown whether existing studies are effective for adult learners in musical education as well as how to effectively design the non-verbal behaviors of robots. This study investigates the effective behaviors of social robots by comparing three kinds of listening behaviors: none, nodding (simple listening), and enjoying (affective listening). We developed a music education support system that consists of a social robot and a MIDI keyboard and conducted an experiment with adult participants. Our experimental results described the advantages of affective-listening behavior during music education over simple listening and non-listening based on gender.

## I. INTRODUCTION

Due to the COVID-19 pandemic, individuals found themselves spending an increased amount of time at home. This shift fueled a notable surge in the number of people who engaged in music-related activities and took music lessons. Several studies have explored how these music activities have evolved, investigating the extent and nature of this newfound interest in music amidst the pandemic worldwide [1-3].

Related to such activity, the landscape of education is evolving. The integration of social robotics has marked a significant shift in pedagogical strategies [4], especially within the realm of music education [5]. For example, past studies focused on motivation and performance improvements in piano lessons with children by supporting their learning skills [6, 7]. A few studies focused on music training for children with autism using social robots as interactive tutors [8, 9]. These studies provided rich knowledge about the effects of social robots in music education in the context of motivation and performance improvements.

However, these studies focused on children as music learners and such verbal behaviors as praise. The former complicates discerning whether existing studies are effective for adult learners in musical education, and the latter complicates addressing how to design robots' non-verbal behaviors, such as listening gestures in musical education. Addressing these gaps could significantly enhance the utility

of social robots in music learning support. Ultimately, leveraging these insights to develop sophisticated robot-assisted learning tools might lead to more effective and enjoyable music education experiences for learners of all ages.

Based on these considerations, we focused on designing the listening behaviors of social robots during music education for adults. We developed a music education support system that consists of a social robot and a musical instrument digital interface (MIDI) keyboard. We conducted an experiment with adults and evaluated our developed system. Its experiment results showed the advantages of affective-listening behavior during music education compared to simple-listening and non-listening.

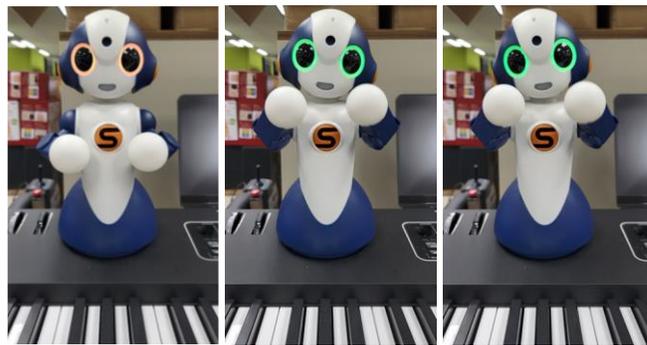


Figure 1. Robot affectively listens to a performance

## II. RELATED WORKS

Social robots are an effective tool for education support [4]. Robotics researchers have developed various kinds of education support systems and experimentally investigated their effectiveness, mainly with children. For example, Efthymiou et al. developed a robotic system to perform a wide range of educational tasks [10]. Soleiman et al. also developed a system using multiple social robots to stimulate social environments for children with autism [11]. From another perspective, Tamura et al. developed an interactive storytelling system and English learning support systems for Japanese children [12, 13].

In the context of education support for children, past studies mainly focused on verbal behaviors. For example, previous studies conducted field trials at elementary schools where a social robot interacted with children for a month to encourage interest in science [14][15]. In both studies, social robots were designed to have conversations about science to stimulate interest in science. Another study also conducted a field trial at an elementary school where human operators controlled a social robot to communicate with children and

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reported that they were calmer and less stressed [16]. Note that although a couple of studies focused on such non-verbal behaviors as encouraging exercising during learning time [17, 18], they less focused on musical education contexts.

Other studies focused on education support with adults. For example, a past work focused on the effects of praise from a robot on motor skill improvements and reported that the number of robots is one essential factor in improving performance [19]. Another reported that both positive and negative feedback improves short-term performance, although positive feedback is better for lowering anxiety in learners and changing attitudes in more positive directions [20]. Another focused on English learning support for adults, reporting that robot teachers can effectively increase their performances [21]. However, these studies also focused on the effects of verbal behaviors in educational contexts and different targets from musical education.

These studies showed effective verbal behavior designs for social robots in education support contexts. Unfortunately, non-verbal behavior designs have not been thoroughly investigated yet. Some studies described the effectiveness of using social robots for education support with adults, but their focuses are different from musical education. One unique point of our study is its focus on the non-verbal behavior design of social robots during musical education with adult participants.

### III. SYSTEM

#### A. Overview

Figure. 2 overviews our developed system that consists of the following components: a MIDI keyboard, a social robot, a performance evaluator, and a behavior selector. The details of each component are described as follows.

#### B. MIDI keyboard

We used YAMAHA CK88, which has the same 88 keys as a standard piano, as a MIDI keyboard device in this study. It sends musical note information (note on/off, note channel, note number, and velocity), to a performance evaluator when the keys are touched and released.

#### C. Social robot

We used Sota, a desktop-sized social robot that is 28 cm high. It has a speaker and a voice synthesis function. The LED on its mouth lights up in conjunction with the volume. Its motions are controlled by a behavior controller whose details are described below.

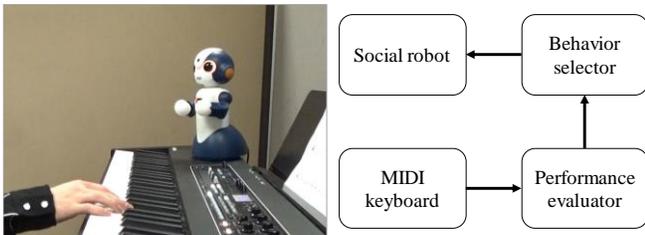


Figure 2. System overview

#### D. Performance evaluator

The performance evaluator judges whether the input information from the MIDI keyboard is correct by comparing it to prepared music score information. For this purpose, the evaluator uses three criteria: matching note number, timings of note on and off.

#### E. Behavior selector

This function controls the robot's motions and speech contents due to the experiment's scenarios and the piano playing evaluated by the performance evaluator. We implemented two different, non-verbal listening behaviors: *simple* and *affective*. For the *simple* behavior, the robot nods when a piano key is touched. For the *affective* behavior, the robot tilts its head left or right and moves its arms (Fig. 1) when the keys are touched. We prepared 27 speeches: 12 pre-defined comments (e.g., "Your playing sounds good even though it's your first trial. Keep up the good work."), 12 compliments based on the performance results (e.g., "You're making fewer mistakes. Your accuracy seems to be improving."), and 3 neutral comments that describe the current trial number (e.g., "You've finished the third one, keep up the pace.").

## IV. EXPERIMENT

#### A. Hypotheses and predictions

Social robots play important roles in the educational support of people [4]. Many studies have described how the effectiveness of positive feedback from social robots improves the performances and the motivations of learners, regardless of their ages. Although these past studies mainly concentrated on the effects of the verbal behaviors of social robots, a similar concept would undoubtedly be effective for non-verbal behavior design. Based on these hypotheses, we made the following predictions:

**Prediction 1:** Participants will be more motivated and play better when the robot provides feedback with both non-verbal and verbal behaviors than when it only provides feedback with verbal behaviors.

**Prediction 2:** Participants will be more motivated and play better when the robot shows affective non-verbal behaviors than when it shows simple non-verbal behaviors.

#### B. Conditions

We prepared three conditions (Fig. 1) and two factors: a *behavior* factor (*none*, *simple*, and *affective*) and a *gender* factor (*men* and *women*).

Concerning the *behavior* factor, in the *none* condition, the robot did not move while it listened to the playing. In the *simple* condition, it nodded when a sound is heard from the keyboard, i.e., using the *simple* behavior described in Section III-D. In the *affective* condition, the robot tilted its head and moved its arms when a sound is heard from the keyboard, i.e., using the *affective* behavior described in Section III-D.

Concerning the *gender* factor, because past studies reported gender differences in learning and musical experiences [7, 22-24], we employed it and conducted an analysis to reveal the gender effects in the context of the musical education of adult participants.

### C. Measurements

We used existing questionnaire scales. First, we employed the modified version of the situational motivation scale (SIMS) [25] to assess the situational intrinsic and extrinsic motivations. This questionnaire item has four subscales: intrinsic motivation (four items), identified regulation (four items), external regulation (four items), and amotivation (four items).

We also employed a modified version of an automated social presence perspective scale based on a previous work [26]. We used the hedonic value (five items), the utilitarian value (three items), intention to use (two items), perceived warmth (three items), perceived competence (three items), and automated social presence (four items).

In addition, we measured the improvement performance ratios between the first trial and the last sessions. The performance ratio of each session was calculated by  $*100$ : correct notes / touched keys.

### D. Procedure

All the procedures were approved by the Advanced Telecommunication Research Review Boards (501-3). First, the participants read explanations about the experiment and how to evaluate the robot in each condition. We employed a within-participant design where they experienced three different conditions (the order of the conditions and the set pieces of music were counterbalanced).

After starting the experiment, the robot explained the task's start timing, and then the participants freely started the tasks at their own timing. Due to the condition, the robot's non-verbal behaviors were different, although the verbal information was identical within the conditions. The participants played the set piece of music seven times; the robot provided voice feedback after each session.

The feedback from the robot changed due to the session numbers. It provided pre-defined feedback at the 1<sup>st</sup>, 2<sup>nd</sup>, 5<sup>th</sup> and 7<sup>th</sup> sessions. At the 4<sup>th</sup> session, its feedback was changed due to the performance changes from the 3<sup>rd</sup> session. At the 6<sup>th</sup> session, the robot's feedback was different depending whether the number of wrong notes was zero or not. At the 3<sup>rd</sup> session, the robot just explained the current session number. After finishing the performances, the participants answered questionnaires and continued the tasks until they experienced all three conditions.

### E. Participants

Twenty-eight people participated: 14 women and 14 men. Their ages ranged from their 20s to their 50s, and their average age was 39.1 (S. D. = 13/4). They applied through a temporary employment agency. Sixteen participants had previously played piano (10 men and 6 women).

## V. EXPERIMENT

### A. Questionnaire results about SIMS

We conducted a two-factor (*behavior* and *gender*) mixed-design ANOVA to analyze the questionnaire results (Figs. 3-6), average and standard error (S.E.). The statistical analysis of the intrinsic motivation did not show any significant differences in the *behavior* factor ( $F(2, 52) = 0.374$ ,

$p = 0.690$ ,  $partial \eta^2 = 0.014$ ), in the *gender* factor ( $F(1, 26) = 0.016$ ,  $p = 0.902$ ,  $partial \eta^2 = 0.001$ ), or in the interaction effects ( $F(2, 52) = 0.207$ ,  $p = 0.769$ ,  $partial \eta^2 = 0.008$ ).

A statistical analysis of the identified regulation did not show any significant differences in the *behavior* factor ( $F(2, 52) = 0.871$ ,  $p = 0.425$ ,  $partial \eta^2 = 0.032$ ), in the *gender* factor ( $F(1, 26) = 0.002$ ,  $p = 0.958$ ,  $partial \eta^2 = 0.001$ ), or in the interaction effects ( $F(2, 52) = 0.150$ ,  $p = 0.861$ ,  $partial \eta^2 = 0.006$ ).

A statistical analysis of the external regulation showed a significant difference in the interaction effects ( $F(2, 52) = 3.832$ ,  $p = 0.028$ ,  $partial \eta^2 = 0.128$ ). There were no significant differences in the *behavior* factor ( $F(2, 52) = 1.400$ ,  $p = 0.256$ ,  $partial \eta^2 = 0.051$ ) or in the *gender* factor ( $F(1, 26) = 0.314$ ,  $p = 0.580$ ,  $partial \eta^2 = 0.012$ ). The simple main effects showed significant differences: *none* < *affective* in the *male* condition ( $p = 0.037$ ) and *simple* < *affective* in the *male* condition ( $p = 0.030$ ).

A statistical analysis of the amotivation did not show any significant differences in the *behavior* factor ( $F(2, 52) = 1.334$ ,  $p = 0.272$ ,  $partial \eta^2 = 0.049$ ), in the *gender* factor ( $F(1, 26) = 0.003$ ,  $p = 0.953$ ,  $partial \eta^2 = 0.001$ ), or in the interaction effects ( $F(2, 52) = 0.433$ ,  $p = 0.651$ ,  $partial \eta^2 = 0.016$ ).

In summary, the robot's listening behavior significantly influenced only the external regulation of the men who showed higher values when the robot's listening behavior was *affective* rather than *none* or *simple*.

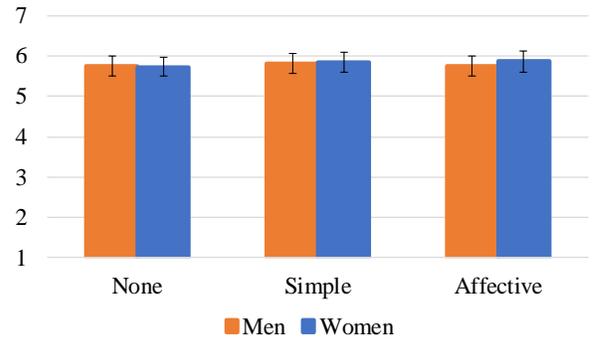


Figure 3. Intrinsic motivation (average and S.E.)

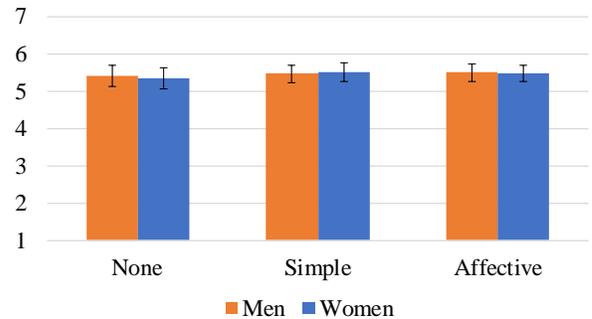


Figure 4. Identified regulation (average and S.E.)

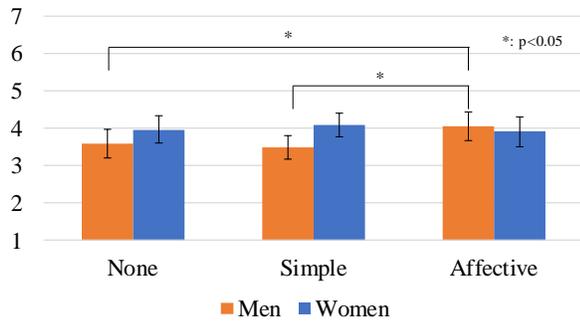


Figure 5. External regulation (average and S.E.)

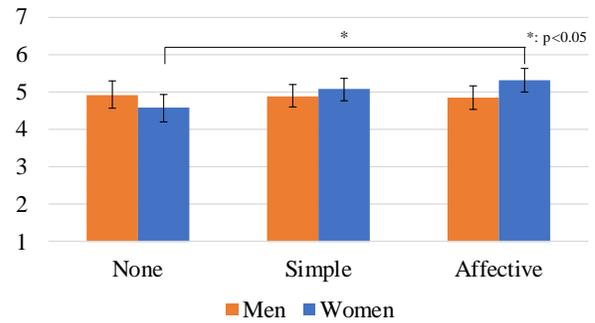


Figure 9. Intention to use (average and S.E.)

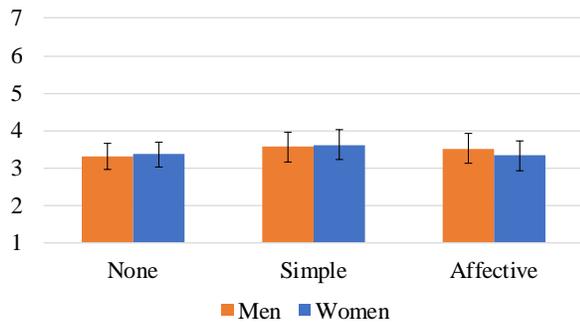


Figure 6. Amotivation (average and S.E.)

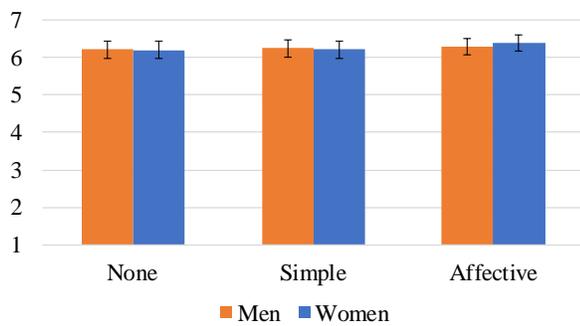


Figure 7. Hedonic value (average and S.E.)

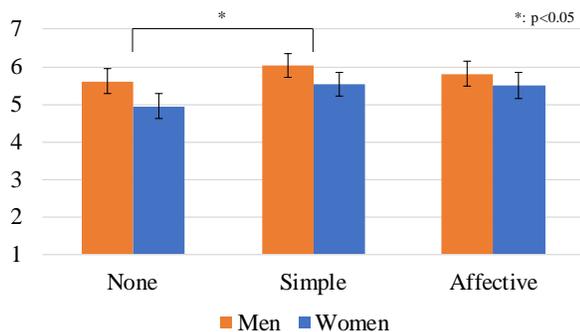


Figure 8. Utilitarian value (average and S.E.)

### B. Questionnaire results about motivations

We also conducted a two-factor (*behavior* and *gender*) mixed-design ANOVA to analyze the questionnaire results (Figs. 7-12). The statistical analysis of the hedonic value did not show any significant differences in the *behavior* factor ( $F(2, 52) = 1.095, p = 0.342, \text{partial } \eta^2 = 0.040$ ), in the *gender* factor ( $F(1, 26) = 0.001, p = 0.975, \text{partial } \eta^2 = 0.001$ ), or in the interaction effects ( $F(2, 52) = 0.169, p = 0.845, \text{partial } \eta^2 = 0.006$ ).

A statistical analysis of the utilitarian values showed a significant difference in the *behavior* factor ( $F(2, 52) = 4.445, p = 0.017, \text{partial } \eta^2 = 0.017$ ). There were no significant differences in the *gender* factor ( $F(1, 26) = 1.386, p = 0.250, \text{partial } \eta^2 = 0.051$ ) or in the interaction effects ( $F(2, 52) = 0.545, p = 0.583, \text{partial } \eta^2 = 0.021$ ). The simple main effects showed significant differences: *none* < *simple* ( $p = 0.023$ ).

A statistical analysis of the intention to use showed a significant difference in the interaction effects ( $F(2, 52) = 3.750, p = 0.030, \text{partial } \eta^2 = 0.126$ ). There were no significant differences in the *behavior* factor ( $F(2, 52) = 2.594, p = 0.084, \text{partial } \eta^2 = 0.091$ ) or in the *gender* factor ( $F(1, 26) = 0.051, p = 0.823, \text{partial } \eta^2 = 0.002$ ). The simple main effects showed significant differences: *none* < *affective* in the *female* condition ( $p = 0.037$ ).

A statistical analysis of the perceived warmth showed a significant difference in the *behavior* factor ( $F(2, 52) = 8.190, p < 0.001, \text{partial } \eta^2 = 0.240$ ). There were no significant differences in the *gender* factor ( $F(1, 26) = 0.541, p = 0.468, \text{partial } \eta^2 = 0.020$ ) or in the interaction effects ( $F(2, 52) = 0.949, p = 0.394, \text{partial } \eta^2 = 0.035$ ). The simple main effects showed significant differences: *none* < *affective* ( $p = 0.002$ ).

A statistical analysis of the perceived competence did not show any significant differences in the *behavior* factor ( $F(2, 52) = 1.389, p = 0.259, \text{partial } \eta^2 = 0.051$ ), in the *gender* factor ( $F(1, 26) = 0.034, p = 0.855, \text{partial } \eta^2 = 0.001$ ), or in the interaction effects ( $F(2, 52) = 0.221, p = 0.803, \text{partial } \eta^2 = 0.008$ ).

A statistical analysis of the automated social presence showed a significant difference in the *behavior* factor ( $F(2, 52) = 4.806, p = 0.012, \text{partial } \eta^2 = 0.156$ ). There were no significant differences in the *gender* factor ( $F(1, 26) = 1.566, p = 0.222, \text{partial } \eta^2 = 0.057$ ) or in the interaction effects ( $F(2, 52) = 0.223, p = 0.801, \text{partial } \eta^2 = 0.009$ ). The simple main effects showed significant differences: *none* < *affective* ( $p = 0.026$ ).

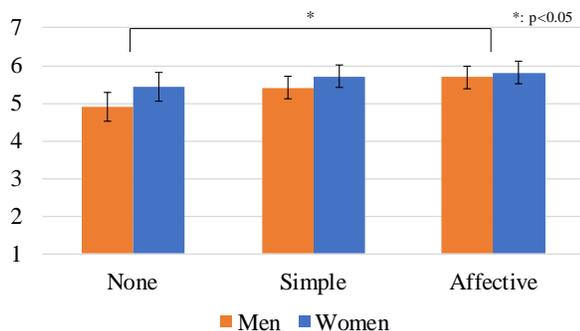


Figure 10. Perceived warmth (average and S.E.)

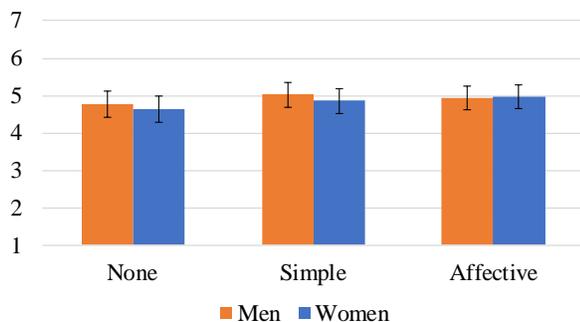


Figure 11. Perceived competence (average and S.E.)

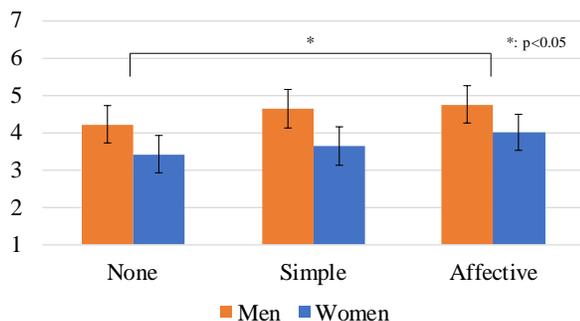


Figure 12. Automated social presence (average and S.E.)

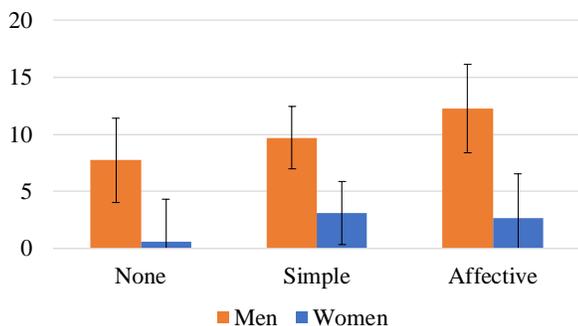


Figure 13. Improved performance ratio between first and last trials (average and S.E.)

### C. Performance

We conducted a two-factor (*behavior* and *gender*) mixed-design ANOVA to analyze the improved performance ratio (Fig. 13). A statistical analysis of the performance

showed a significant difference in the *gender* factor ( $F(1, 26) = 17.100, p < 0.001, \text{partial } \eta^2 = 0.397$ ). The results did not show any significant differences in the *behavior* factor ( $F(2, 52) = 0.481, p = 0.621, \text{partial } \eta^2 = 0.018$ ) or in the interaction effects ( $F(2, 52) = 0.112, p = 0.894, \text{partial } \eta^2 = 0.004$ ).

### D. Summary

In summary, the robot's listening behavior significantly influenced some of the questionnaire items, such as the utilitarian value, the intention to use, the perceived warmth, and the automated social presence. These differences are only shown between the *none* and *affective* conditions for men. We found no significant differences in the performance. Therefore, prediction 1 is partially supported; prediction 2 is not supported.

## VI. DISCUSSION

### A. Implication

This study offers practical implications. The affective-listening behaviors showed some advantages compared to non-listening behaviors, especially in men. A past study also reported that male players showed higher motivation when they interacted with a robot that supported the self-assessment process in musical training [7]. Although that past study focused on children, instead of adults, a similar phenomenon from different trials would contribute to design robot's behaviors in musical training contexts.

The improved performance ratio also suggests the effectiveness of musical training with a social robot for men, even though the results did not show any significant differences. In this study, since fewer women had previous music experience than the number of men, perhaps the training might be effective for women. However, our experiment results showed contrary phenomena from our assumption. Investigating an effective musical training method by gender is an interesting future research topic.

### B. Limitation

This study has several limitations. First, we only used a specific robot (Sota) and a specific instrument. Therefore, testing with different robots and instruments is essential. Moreover, most of the participants were adults, who are the beginners or no experience playing instruments. Therefore, the effects toward more experienced people or children are not investigated yet. Despite these limitations, we believe that our study provides basic knowledge about motivational improvements fueled by a robot's listening behavior during music lessons.

## VII. CONCLUSION

This study investigated the effects of robot's listening behavior on motivation and performance improvements during music instrument lessons. We developed a system that consists of a MIDI keyboard, a social robot, a performance evaluator, and a behavior selector. The system enables the robot to provide both verbal and non-verbal feedback, such as affective-listening behaviors. We conducted an experiment with human participants who played a keyboard under robot feedbacks. The experimental results showed that the robot's affective-listening behavior significantly influenced the

external regulation of men more than the simple- and non-listening behaviors. The affective-listening behavior contributed more to the participants' motivations than the non-listening behaviors, although the performances did not significantly improve.

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